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Materials Science R&D in Dresden, Saxony and Germany

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These reports summarize global activities of S&T Associate Directors of the Office of Naval Research International Field Offices (ONRIFO). The complete listing of newsletters and reports are available under the authors' by-line on the ONRIFO homepage: <http://www.ehis.navy.mil/onrnews.htm> or by e-mail to respective authors.

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1. Summary

The European Office of Aerospace R&D (EOARD) organized a trip to Dresden and the surrounding areas to investigate the burgeoning material science R&D and manufacturing in the area. ONRIFO participated in this trip. The members of the combined EOARD and ONRIFO party were:

Dr. Alex Glass, visit organizer, EOARD

Col. Gerry O'Connor, EOARD

LCOL Charles Ward, EOARD

Dr. Paul Fleitz, AFRL, Wright Patterson

Dr. Joel House, AFRL, Elgin AFB

Dr. Michael Stropki, Department of Material Technology, USAF

Dr. Michael Pestorius, ONRIFO

Dr. Phil Parrish, ONRIFO, co-organizer

Dr. Mark Taylor, ONRIFO

Mr. Thomas Hermsdorfer, the Landtag (legislature) delegate from Chemnitz and the Saxony Development Office sponsored the trip. Gail Shipley, a US citizen and Mr. Hermsdorfer's assistant, assisted us throughout the visit.

2. Introduction

The visit consisted of a fast paced two days of overview presentations and lab visits with a series of universities and R&D institutions. A few general comments:

- a. Dresden was part of East Germany (DDR) and suffered extensive damage in WW II. Since German unification, huge sums have been spent in the former DDR in public services, transportation and other infrastructure. Although this part of Germany still has yet to completely catch up to western Germany, this investment in highways, bridges, trains and airports is evident. Dresden has a new and very attractive airport, for example.
- b. Of direct importance to our visit objective, every lab, whether in a university or R&D institution, was absolutely first class. Equipment from microelectronic fabrication to huge metal presses was new, very clean and very well maintained. Workspaces and laboratories were notably clean, clutter-free and orderly. Everyone from lab directors and faculty members (often the same person) to technicians were knowledgeable, open and English speaking.
- c. Enrollment at the technical universities (TU) declined drastically after unification as young people abandoned the former DDR for western Germany. That trend appears to have been reversed. When questioned, TU faculty members reported record levels of students.
- d. It is difficult to measure workyear costs because it is not always evident that all sources of income are being shown, but using figures provided it appears that the average workyear cost in the TUs is about 100K € and about 120K € in the R&D institutions. Salaries are about half of this total number on average.
- e. We visited several of the 56 Fraunhofer Institutes. There is not an exact parallel in the US system for these institutions. Germany has four large science societies: the Max Planck Society consists of institutions that are dedicated to basic science research, the Fraunhofer Society is committed to technology transition from universities to industry, the Helmholtz Society funds the development, construction and operation of large-scale facilities

such as particle accelerators and the Leibniz Society consists of institutions that formerly formed the DDR Academy of Science. No Max Planck or Helmholtz institutions were visited and they will not be considered here. The Fraunhofer and Leibniz institutions receive a mix of federal and state (in this case, Saxony) funds that appear to cover about 50% of their costs. The balance of their funding is contractual from either government or industry. The base portion of the government funding is tied to the level of industrial funding. The institution employees are not government employees, but they appear to be in an in-between status that has no clear parallel in the US.

- f. Saxony has a 17.5% unemployment rate.

Every institute and university that we visited has good connections to the US. In some cases these connections are to DoD organizations and labs.

3. Technical University Dresden, Institute for Applied Optics

Tuesday, 2/05/2002: Visits are reported very briefly. In most cases web addresses are available for more extensive information.

Our first visit was to the Technical University Dresden Institute for Applied Optics (**Institut für Angewandte Photophysik, IAPP**, <http://www.iapp.de/>). Our host was Prof. Lukas Eng. He discussed research work in ultra fast (femtosecond) optical spectroscopy for probing the dynamics of organic molecular crystals and low-dimensional semiconductors; organic molecular beam epitaxy; metal micro- and nano-structures; and ferroelectrics. Prof. Eng also discussed the ability to coevaporate luminescent organic species, e.g., perylene-3,4,9,10-tetracarboxylic-dianhydride (PTCDA) in a SiO₂ matrix to create luminescent materials with a high quantum-efficiency for optoelectronic applications. He also presented his work on functionalization of DNA molecules, chemically bonding Pt or Pd to form DNA/Pt or DNA/Pd quantum wires for interconnects. They are investigating these structures for evidence of quantized conductance along the DNA stand. It is recommended that ONRIFO follow up on this work in its considerations of potential future activities in the nano-bio technology area. Prof. Helmut Eschig then briefed the Institute for Solid State and Materials (**Institut für Festkörper-und Werkstofforschung, IFW**, <http://www.ifw-dresden.de/>). This 400 person institute is a Leibniz Society member with an annual budget of 19.6 M € with additional project funding of 6.5 M €. He briefly discussed each of their five main research areas: superconductivity and supermagnets (including 16 Tesla permanent magnets), magnetism and magnetic materials, conjugated carbon systems (including fullerenes and carbon nanotubes), metastable metallic alloys, and microelectronics (including surface acoustic wave devices). Professor Eschig mentioned numerous international collaborations within each of these areas. The tour of the Institute for Applied Optics was typical of our several tours. Of particular interest was the production of multiwall nanotubes, which were then filled with iron nanoparticles to form nanotube wires, and the work on nano imprint lithography to fabricate surface acoustic wave devices. The labs were well equipped and maintained. Although, in general, briefers drew a sharp distinction between the university and the institutes, their physical facilities are usually together and appear to be easily accessible by both staff members and students. Often, faculty members are also appointed in the institutes as in this case.

4. Fraunhofer Institute for Applied Material Research

Tuesday afternoon began at the Fraunhofer Institute for Applied Material Research (**Institut für Angewandte Werkstofforschung, IAW**, <http://www.iws.fhg.de/>).

- a. Dr. Andreas Leson presented a short overview of the Fraunhofer Society. The society was founded in 1949 with an applied research and development focus. There are currently 56 component institutes with about 11,000 employees and 1B € in annual funding. He then briefed his branch of IAW, the Institute for Material and Beam Technology, IWG. This 170-employee institute has extensive laser, TEM, SEM material characterization equipment and CNC machines. They are involved in laser cutting & welding, thin film laser coating, plasma technologies and microstructure analysis. Of particular interest were several projects using advanced deposition techniques: Ni/C multilayers are deposited by pulsed laser deposition in a magnetron field to form multilayers with period thickness of 3-5 nm, with a claimed precision of less than 0.1nm; amorphous carbon coatings for low friction on fibers and tools (project with Audi on cutting, stamping and forming tools) are being deposited by pulsed arc plasma deposition using pulsed and oscillating laser beams to focus the deposition point in a vacuum of 10^4 Pascals, yielding coatings free of hydrogen and with much higher (2X) hardness than that found in traditional diamond-like carbon; repair of turbine blades by laser build up welding of superalloys with very little final machining required; and laser beam finishing of natural stone surfaces to form nonslip finishes for walkways and flooring applications.
- b. Dr. Bernd Kieback briefed his Institute for Powdered Metallurgy and Composite Materials, which is part of the larger Fraunhofer Institute for Manufacturing and Advanced Materials in Bremen (<http://www.epw.ifam.fhg.de/>). They investigate high performance sintered materials, tribology and high temperature materials, cellular metallic materials, structures built of hollow metal spheres, metal matrix composites and dispersion strengthened materials. The institute also has an effort in materials such as carbon reinforced Cu, SiC particle reinforced Cu and Cu/Mo alloys for thermal management applications in the electronics industry. Their primary customer (as it was for several of the institutes) is the automobile industry. This institute also has a branch office in Delaware. Dr. Kieback, in addition to his institute directorship, has a faculty appointment at TU Dresden.

Dr. Andreas Schönecker then briefed the Institute for Ceramic Technology and Sintered Materials (**Institut für Keramik Technik und Sinterwerkstoff, IKTS**, <http://www.ikts.fhg.de/>). IKTS works with piezo, ferro and dielectric materials and has a US operation, Smart Material Corporation near Sarasota, FL (<http://www.smart-material.com/>). They make PZT micro fibers and tubes that are then aligned, embedded in resin, cut and polled to form 1-3 transducers. This method is different from the two familiar 1-3 manufacturing techniques, slice and dice of solid PZT or injection molding and may be a superior method. Dr. Andreas Krell followed Dr. Schönecker. He briefed their work on ceramic armor and a new development, transparent armor. In the effort on ceramic armor, they claim a 50% increase in ballistic

resistance based upon a nanoscale grain sized alumina with minimum grain growth and porosity after sintering. Lockheed Martin is testing this material.

5. Research Center Rossendorf

We then bussed to the Research Center Rossendorf (**Forshungszentrum Rossendorf, FZR**, <http://www.fz-rossendorf.de/>). This large center was, until December 31, 1991, the DDR Institute for Nuclear Research (**Institut für Kernforschung**) and employed 1500 people. The mission is now more diversified and the employment total is 420 permanent and about 135 contractor personnel plus 65 students. FZR is a Leibniz Society member with an interdisciplinary applied technology focus. The Institute has an annual budget of 47 M € with an additional 7 M € in project funding. This institution was not as new and well maintained as the others we saw and it was hard not to come away thinking that it was an institution with only a limited future. Prof. Frank Pobell gave an overview brief. The large German uranium mines were near Dresden and they were a prime objective of the Russian takeover of this area after the war. ZFR's portfolio includes work on environmental issues, radiation safety, positron emission tomography, nuclear physics and material science. He also briefly mentioned free electron laser work in the far infrared. Prof. Möller, who briefed ion beam applications for MBE, thin film deposition and surface analysis, followed him. Dr. Pestorius of ONRIFO had, in the preparation to this trip, expressed some interest in nuclear power research and, as a consequence, had a special program set up by the Institute for Safety Research, headed by Dr. Udo Rindelhardt (**Institut für Sicherheitforschung**, <http://www.fz-rossendorf.de/>). This group had a distinctly melancholy air about them. Germany derives 35% of its power from nuclear reactors, but the government has recently passed a law requiring the complete phase out of nuclear power generation within the next 20 years. The researchers have money only for safety and reliability studies and it will be very difficult to attract any new researchers into this field. Dr. Ulrich Rohde briefed on core accident analysis. He covered various reactor accidents, which are analyzed with 3-D CFD codes. They also have 3-D neutron kinetics distribution codes. He later conducted a tour through a one-fifth-scale Pressurized Water Reactor (PWR) plant made of transparent plastic for flow visualization. Mr. Firke, who discussed material behavior under neutron flux, followed Dr. Rohde. They have extensive equipment for analysis of reactor vessel properties as a function of core life. The last speaker was Dr. Gunter Gerbeth who works in the area of magneto hydrodynamics (MHD). Dr. Pestorius later visited his lab where he has control surfaces that look very much like submarine fairwater and stern plane models. He has experimental data showing how the Lorentz force decreases turbulent flow across the underside of the plane. Unfortunately this force also leads to bubble flow, which Dr. Gerbeth thought could be reduced by the use of AC vice DC current excitation. He is researching MHD on cruise ship stabilizers under Thyssen Krupp funding and is collaborating with Dr. James Ming of NUWC on possible MHD uses. He postulated that MHD could be used for ship control with no moving rudder surfaces. MHD is an idea that has been around for a long time and enjoyed its best success in Tom Clancy's book Hunt for Red October. It is probably too inefficient for other than niche application.

6. TU Bergakademie, Freiberg

Wednesday, 6 February 2002

A long bus ride deposited us in the market square of Freiberg, a former mining town southwest of Dresden and site of the TU Bergakademie Freiberg. We were briefed on the Institute for Metal Forming (**Institut für Metallformung**, <http://www.imf-freiberg.de/>). This institute is linked to the four universities of Dresden, Chemnitz, Freiberg and Zwickua. The director is Prof. Rudolph Kawalla. He is also a TU Freiberg professor. The institute, while not a Fraunhofer or Liebniz member, is similarly funded with 50% Saxony funding and 50% contractual. The TU Freiberg has 3700 students in 7 departments and is growing.

7. Research Institute for Non-ferrous Metals

Prof. Kawalla was followed by Mr. Heino Pachschröll, CEO of the Research Institute for Non-ferrous Metals (**Forschungsinstitut für Nichteisenmetalle**, **FNE**, <http://www.fne-freiberg.de/>), a private company. He has good links to the US and Canada and works in metal production and processing. A strong current interest is magnesium sheet metal for the automotive industry. He also mentioned lead-free soldering pastes, ultrasonic soldering and welding (at 20Khz), lightweight self lubricating parts for the auto industry and combined metal and ceramic parts. Mr. Pachschröll was one of the more entrepreneurial people that we met. The presentations closed with Mr. Gert Goldhahn, who discussed TU Freiberg's metal forming labs. These labs have hot and cold presses, rolling mills, forging units, furnaces and drawing facilities. We were then taken on a tour of these facilities, which were a closed area in DDR days. Perhaps the only US university that has facilities that compare with these heavy metal working labs is in the Metallurgy Department at Colorado School of Mines, Golden CO.

8. TU Chemnitz, Center for Microtechnologies

We then bussed to Chemnitz for meetings at TU Chemnitz, Center for Microtechnologies (Zentrum für Mikrotechnologien, ZfM, <http://www.infotech.tu-chemnitz.de/>). Prof. Thomas Gressner heads ZfM, which is a component of the TU Chemnitz Department of Electrical Engineering and Information Technology. TU Chemnitz has 8000 students in 6 science and engineering departments plus economics. Its annual budget is roughly 20 M €. Prof. Gressner directs both ZfM and the Fraunhofer Institute for Reliability and Microintegration (Institut für Zuverlässigkeit und Mikrointegration, IZM). The relationship between the university and the associated Fraunhofer institute, in this case IZM, often appeared blurred with no close parallel in US universities. The ZfM work at TU focused on fabrication and handling of silicon wafers, MEMs and nanotechnology. It overlaps with the IZM work in semiconductor assembly, packaging and chip handling. They are partnered with AMD, Applied Materials, Infineon (formerly Siemens Semiconductors), Motorola, Fujitsu, LETI and others. Dr. Gressner was followed by Dr. Stephan Schulz, also of ZfM who discussed low permittivity dielectrics for semiconductor applications. ZfM has developed dielectrics that compete with Honeywell nanoglass products. It is working on mesoporous silica films (aerogels, xerogels) with 40 –

75% porosity and dielectric constant values of $1.7 < k < 2.5$. Compatibility with existing semiconductor manufacturing processes and process integration are key boundary conditions in the institute's work. Dr. Karla Hillyer of IZM then presented work on material aspects of MEMs and bonding processes in multi-wafer MEM devices, in particular, their work on low temperature direct wafer bonding using oxygen plasma activation to clean SiO₂ off of silicon.

9. Institute for Machine Tools and Forming Technologies, Fraunhofer

Dr. Andreas Schubert of yet another Fraunhofer Institute, the Institute for Machine Tools and Forming technologies (Institut für Werkzeugmaschinen und Umformtechnik, IZM, <http://www.infotech.tu-chemnitz.de/~zfm/myfab/>) covered their activities, which include metal foams, metal sheets, metal-plastic composites and forming of micro-metal parts. This last activity produces parts that appear to be a competitor for MEMs made using silicon fabrication techniques. We later toured the IZM metal working laboratories and found them to be very well equipped with the newest devices, spotlessly clean and neat and operated by knowledgeable English speaking technicians. We found similar conditions in all the facilities we toured.

Following Dr. Schubert's talk, we had two additional short talks from TU faculty members. Prof. Günter Mennig of the department of Mechanical Engineering and Plastics Technology discussed lightweight, high strength plastics for the automobile and sporting goods industries. Prof. Lothar Meyer, Material Science Department covered his work on the characterization of materials under high strain rates. He has numerous industrial connections and has been involved in US/German DEA on armor/anti-armor for over 25 years.

10. Observations

1. There is a close and sometimes hard to sort out interlinking between the TUs and the Fraunhofer Institutes. There is not a clear parallel with US universities and either government or private sector labs. The institute labs are often located in campus buildings and faculty members are appointed in both the TU and the associated institute.
2. Every space visited, whether in a TU or an institute, was well equipped, very clean and well presented, and staffed by capable, mostly young personnel.
3. Transportation infrastructure in Saxony appeared to be very adequate.
4. The organizations we visited had virtually no defense business.
5. Most organizations visited had good US connections and in some cases US subsidiaries.
6. The best opportunities for near term collaboration appear to be in the 1-3 PZT transducers work of Dr. Andreas Schönecker and the Technical University of Dresden work by Prof. Eng on DNA/Pt and DNA/Pd quantum wires for interconnects to functionalize DNA molecules.
7. While our measurement data is admittedly sparse, personnel work-year costs in Saxony appear to about one half those in US DoD labs.

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